

TABLE 1.—Condensed form showing weather conditions prevailing over the Northwest during November, 1905—Continued.

Causal weather.											Resulting weather in Wisconsin.									
Date.	High.		Low.		Nearest rain during past 12 hours.	Temperatures, 24-hour changes, and precipitation.						Date.	Temperatures, 24-hour changes, and precipitation.							
	Location.	Strength.	Location.	Strength.		Moorhead.	Bismarck.	Huron.	Pierre.	Omaha.	N. Platte.		La Crosse.	Madison.	Green Bay.		Milwaukee.			
		Inches.		Inches.									a. m.	p. m.	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.
26	Dakotas	30.0	East Ontario	29.7	Montana, Lake Superior.	28	20	24	30	36	28	27	30	36	30	36	28	36	38	40
	Saskatchewan	30.1				.....	-10	-8	-6	.....	.....		.....	+6	.....	.....	-6	+6	.....	+6
						.....	.....	.....	.....	.....	.....		.....	.16	.....	T.	.....	.....	.....	.....
27	Saskatchewan	30.5	Utah.....	29.3	Dakotas, Montana	22	16	30	30	36	32	28	44	36	44	42	38	38	42	52
						-6	.....	+6	.....	.....	.....		+14	.....	+14	+6	+10	.....	.....	+12
						.04	.04	.....	T.	.....	.....		.68	T.	T.	.....	.48	.....	.36	.....
28	Saskatchewan	30.4	Minnesota	29.15	Wisconsin, Iowa, Dakotas, Minnesota.	22	6	28	16	36	24	29	18	10	20	16	28	14	26	22
						.....	-10	.....	-14	.....	-8		-26	-26	-24	-26	-10	-24	-16	-30
						.96	.52	.68	.36	.36	.08		T.	.....	T.	T.	T.	T.	T.	T.
29	West Dakotas	30.6	East Ontario.....	29.4	Wisconsin, Iowa, Dakotas, Minnesota.	-6	-8	0	2	8	6	30	2	18	8	18	10	18	12	26
						-28	-14	-28	-14	-28	-18		-16	+8	-12	.....	-18	.....	-14	.....
						.38	.22	.04	.10	T.	.24		.....	.....	.....	.....	.....	.....	.....	T.
30	Minnesota	30.8	Utah.....	29.9	Upper Michigan, Oregon	-26	-14	-12	-6	4	4	Dec.	22	.....	20	26	26	32	30	32
	British Columbia.	29.8				-20	-6	-12	-8	.....	.....	1	+20	.....	+12	+8	+16	+14	+18	+6
					

The rules obtained by this method are of course largely empirical and are not to be depended upon absolutely in making practical forecasts. Watchfulness of local conditions and careful consideration of the daily peculiarities and abnormalities in the regular march of weather conditions across the country are of much importance for making accurate local forecasts. On the other hand it will hardly be possible for anyone who has a fair knowledge of meteorological phenomena to pursue the study of the problem of forecasting as outlined above without obtaining a better knowledge of its fundamental principles.

SPECIMEN RULES.

From a limited amount of data the following specimen rules for the month of November have been formulated, applicable particularly to the southern portion of Wisconsin.

1. A decided 24-hour rise in temperature (20° or more) in eastern South Dakota, closely attending a low, except when no rain has fallen in the Northwest, indicates rain the following night in Wisconsin.

2. A decided low (central isobar 29.3 inches or lower) in the Southwest (Kansas, Colorado, or Utah), with rain in North Dakota, indicates rain the next night period.

3. A general rise of temperature in the Dakotas, amounting to 6° or more, accompanied by rain in the Southwest (Oklahoma and Kansas) indicates rain either the next night or the following day.

4. A. M. rain in Nebraska, except when attending a fall in temperature, will be followed by rain in one of the periods forecasted for.

5. A distinct high in Iowa, Kansas, or Missouri, with a low northwest of it, will be followed by rising temperature in both periods. Exceptions: The high over Kansas must be 30.4 inches, or more, at center; when the temperature is comparatively very low in the Dakotas, no rise will follow.

6. A decided rise of temperature in the Dakotas, attending a low, indicates a rise in the a. m. period.

7. A low in Alberta or British Columbia, unless disturbing pressure centers intervene, indicates a p. m. temperature rise.

8. A decided low in the Southwest will cause an a. m. temperature rise.

9. A 20° fall in temperature in the Dakotas, following a low, indicates an a. m. fall in temperature.

10. A low (central isobar 0.2 inch below the normal) over Minnesota, Superior, or Wisconsin, except when there has been a decided rise in the Dakotas, indicates an a. m. temperature fall.

11. A similar low over Minnesota indicates a p. m. temperature fall.

12. Fair weather, with stationary temperature, is generally indicated in all cases not covered by the preceding rules.

The foregoing rules, applied to the data from which they were derived, gave forecasts with a verification (under the present system) of 94 per cent for precipitation, and 85 per cent for temperature. These percentages would not of course hold absolutely for other data, but it would seem that any loss in percentage of verification should be partially compensated by the forecaster's familiarity with the existing weather movement.

THE EVAPORATION OF ICE.¹

By F. C. MITCHELL, Camden, Me.

The object of this series of experiments on the evaporation of clear ice and snow is to determine to what degree the evaporation is affected by (a) temperature, (b) amount of atmospheric pressure, (c) velocity of wind, and (d) area of exposed surface.

Experiments have been performed on the evaporation of liquids and several laws stated, and it has been assumed that the laws for the evaporation of solids like ice follow those for liquids.

Dalton stated that:

Evaporation is that process by which liquids and solids assume the gaseous state at their free surfaces. The rate of evaporation depends upon temperature of the liquid or solid, the extent of the exposed surface, and the facility with which the gaseous particles can escape from the neighborhood of the surface either by diffusion through the air or by the motion of the air itself.

This is equivalent to saying that evaporation of liquids and solids depends upon temperature, amount of exposed surface, atmospheric pressure, humidity, and wind.

The evaporation of a liquid may be seen at any time, and that of a solid such as ice may be observed in the winter and spring, when snow disappears with the temperature continuously below 0° C. Some chemical substances, such as camphor and iodine, evaporate at ordinary pressure and temperature without first passing into the liquid state.

Two different methods were used in my experiments, which continued thruout the first three weeks of the month of March, 1906, whenever the temperature remained below 0° C. During the first two weeks of the month the conditions were

¹ These investigations were suggested to me by Prof. James S. Stevens, of the University of Maine, and presented as a thesis to the department of physics of that institution, at Orono.

quite favorable. Attempts were made previous to March, but the weather was so mild for a greater part of the winter months (December, January, and February) that nothing could be accomplished from which any conclusions could be drawn.

FIRST METHOD.

A piece of clear ice, in a cubical form, measuring 5 cm. on a side or 125 cm.³ was weighed in a small wire holder so arranged that ice was exposed to the air freely on all sides. After each weighing the ice with holder was taken from the balances and suspended in the free atmosphere. The temperature was carefully taken, to tenths of a degree, and the barometric pressure to hundredths of an inch. These readings of weight, temperature, and pressure were recorded every hour during the day from 9 a. m. to 4 or 5 p. m., for seven successive days, except part of the fourth day. (See Table 1). A smaller piece of ice was used on the last three days instead of the original piece.

This experiment was performed in the unfinished attic of the Camden High School building.

A maximum and minimum thermometer hung near the piece of ice, and from this the maximum and minimum temperatures were taken for each night excepting the first—February 28.

The average evaporation per hour was computed for five of the nights. It was found that this hourly evaporation during the nights was considerably less than during the days.

TABLE 1.—Data obtained by weighing method.

[Surface area, 150 cm.² Volume, 125 cm.³]

Date.	Hour.	Temp.	Pressure.	Weight of ice.	Loss in weight per hour.	Remarks.
1906.		° C.	Inches.	Grams.	Grams.	
February 28.	9	-8.0	29.50	115.360	.....	Cloudy.
Do.	10	-8.0	29.50	115.224	0.136	
Do.	11	-8.1	29.50	115.089	0.135	
Do.	12	-8.0	29.52	114.954	0.135	
Do.	1	-7.8	29.51	114.816	0.138	
Do.	2	-7.3	29.50	114.676	0.140	
Do.	3	-7.1	29.50	114.533	0.143	
Do.	4	-6.9	29.49	114.386	0.147	
Average....	9 to 4	-7.7†	29.50†	.....	0.139	
Feb. 28-Mar. 1						
Average....	4 to 9	.....	(29.60)	.....	0.110	Minimum temperature, -11° C.
March 1.	9	-7.3	29.70	112.511	.....	Partly cloudy.
Do.	10	-7.1	29.70	112.362	0.149	
Do.	11	-6.9	29.71	112.206	0.156	
Do.	12	-6.6	29.70	112.048	0.158	
Do.	1	-6.0	29.71	111.888	0.160	
Do.	2	-5.2	29.70	111.723	0.165	
Do.	3	-4.9	29.72	111.559	0.164	
Do.	4	-5.1	29.72	111.395	0.164	
Average....	9 to 4	-6.1†	29.71†	.....	0.159	
March 1-2.						
Average....	4 to 9	.....	(29.88)	.....	0.116	Minimum temperature, -10° C.
March 2.	9	-8.1	30.05	109.430	.....	Fair.
Do.	10	-8.0	30.09	109.292	0.138	
Do.	11	-7.6	30.10	109.150	0.142	
Do.	12	-7.1	30.00	109.003	0.147	
Do.	1	-6.5	30.02	108.838	0.165	Error due to hasty reading.
Do.	2	-6.2	30.00	108.695	0.143	
Do.	3	-5.7	29.95	108.535	0.160	
Do.	4	-5.5	29.93	108.375	0.160	
Do.	5	-6.0	29.93	108.203	0.172	
Average....	9 to 5	-6.7†	30.01†	.....	0.153	
March 2-3.						
Average....	5 to 8	.....	(29.56)	.....	0.156	Minimum temperature, -6.5° C.
March 3.	8	-5.0	29.20	105.857	.....
Do.	9	-3.7	29.00	105.687	0.170	
Do.	10	-1.0	29.00	105.509	0.178	
Do.	11	0.0	*	(103.807)	(1.702)	

*No reading taken. †The first and last readings of the series were given half weight.

On March 3, at 11 o'clock, the temperature became 0° C., and as the ice began to melt no further readings were taken.

The dimensions of the cubical piece of ice used decreased in the seventy-four hours from 5 cm. to 4.85 cm., or the volume from 125 cm.³ to 114.07 cm.³, while the weight decreased from

115.360 g. to 103.807 g. or a loss of 11.553 g., making an average hourly decrease by evaporation of 0.156 g., approximately.²

From these data it may be seen that the amount of evaporation increases as the temperature increases when the pressure remains constant, and as the experiment was performed indoors there was no wind or air currents. The glass sliding door of the balance was kept down while all weighings were being made to avoid the effect of heat on the experiment. During each of these days the pressure was quite constant. February 28 it was about 29.5 inches, March 1 approximately 29.7, while on March 2 it was 30, and during the time on the 3d that the temperature was below 0° C. the pressure was 29 inches, so we may consider each of these days as having a fairly constant barometric pressure, and consequently determine the effect of temperature change during each day.

During the first day the temperature increased from -8° C. to -6.9° C., while the amount of evaporation increased from 0.136 g. to 0.147 g. per hour. The second day the temperature increased from -7.3° C. to -5.1° C., the evaporation per hour from 0.149 g. to 0.164 g. The third day the temperature increased from -8.1° C. to -6° C., the evaporation from 0.138 g. to 0.172 g. per hour.

It may be seen also that the amount of evaporation increases as the atmospheric pressure increases. This is due, without doubt, to the fact that the relative humidity of the free atmosphere is generally less during high pressures than during low pressures. It also seems that the evaporation is less on cloudy days than on partly cloudy, and less when partly cloudy than when fair. At 2 p. m. the first day is noticed a temperature of -7.3° C.; at the end of an hour, -7.1° C.; while the amount of evaporation for the hour is 0.143 g. On the second day at 9 and 10 a. m. we find the same temperatures but an amount of evaporation of 0.149 g., or an increase of 0.006 g. per hour. On the first day from 9 to 10 a. m. we find an evaporation of 0.136 g., while on the third day for the same hour we have 0.138 g. evaporation. As all other conditions³ apparently remain the same the conclusion is that the evaporation increases with atmospheric pressure, or with a decrease of humidity.

The minimum temperature for each night was recorded by the maximum and minimum thermometer. It was found that the amount of evaporation per hour during the night is considerably less than during the day, the average for the three nights being 0.126 g. per hour, while the average for an hour during the first three days is 0.151 g.

Next a piece of ice in the cubical form, as nearly as could be cut and shaved, with sides of 3.54 cm. or volume 44.356 cm.³, was used, and the data in Table 2 obtained, the method of procedure being the same as in the previous case. It will be noticed that the amount of exposed surface in this case is approximately one-half as great as in the previous part of the work.

The data in Table 2 were obtained by the same method, the same apparatus, and in the same place as the data in Table 1.

The average evaporation was 0.0632 g. per hour. The area of the exposed surface was approximately one-half of that in the first part, being 75.18 cm.², while in the first it was 150 cm.². The amount of evaporation was approximately one-half, thus justifying the statement that the amount of evaporation is proportional to the area of the exposed surface.

The second table shows, as the first did, that the amount of evaporation increases as the temperature increases.

²The tenfold rate of loss in weight in the last hour makes one suspicious that melting occurred before the weighing; probably a truer average would be found by computing merely for the seventy-three hours ending at 10 a. m., March 3. The loss in weight during this period was 9.851 g., which amounts to an average loss per hour of 0.135 g.—EDITOR.

³There was presumably a decrease in the exposed surface area, at a rate approximating, on the average, 2 per cent a day; this would make the increase of evaporation all the more notable.—EDITOR.

TABLE 2.—Data obtained by weighing method.

[Surface area, 75.18 cm.² Volume, 44.36 cm.³.]

Date.	Hour.	Temp.	Pres- sure.	Weight of ice.	Loss in weight per hour.	Remarks.
		° C.	Inches.	Grams.	Grams.	
1906.						
March 4.	9	-10.5	30.30	40.810		Fair.
Do.	10	-10.1	30.30	40.746	0.064	
Do.	11	-9.6	30.31	40.671	0.075	
Do.	12	-8.5	30.31	40.606	0.065	
Do.	1	-8.0	30.30	40.539	0.067	
Do.	2	-7.3	30.28	40.473	0.066	
Do.	3	-5.1	30.29	40.406	0.067	
Do.	4	-5.2	30.30	40.341	0.065	
Do.	5	-5.4	30.30	40.273	0.068	
Average	9 to 5	-7.7†	30.30†		0.067	
March 4-5.						
Average	5 to 9		(30.29)		0.060	Minimum temperature -12° C.
March 5.	9	-8.9	30.28	39.313		Fair.
Do.	10	-8.2	30.26	39.251	0.062	
Do.	11	-7.3	30.25	39.186	0.065	
Do.	12	-6.1	30.25	39.116	0.070	
Do.	1	-5.0	30.25	39.054	0.062	
Do.	2	-4.9	30.26	38.994	0.060	
Do.	3	-5.2	30.27	38.931	0.063	
Do.	4	-6.0	30.27	38.863	0.068	
Do.	5	-7.8	30.27	38.799	0.064	
Average	9 to 5	-6.4†	30.26†		0.064	
March 5-6.						
Average	5 to 9		(30.18)		0.061	Minimum temperature -10.5° C.
March 6.	9	-6.0	30.10	37.823		Cloudy in a. m.
Do.	10	-5.4	30.11	37.757	0.066	Fair in p. m. with heavy wind.
Do.	11	-4.3	30.08	37.690	0.067	
Do.	12	-3.6	30.08	37.620	0.070	
Do.	1	-3.4	30.07	37.555	0.065	
Do.	2	-2.2	30.09	37.487	0.068	
Do.	3	-2.0	30.09	37.418	0.069	
Do.	4	-1.5	30.09	37.346	0.072	
Do.	5	-1.5	30.08	37.271	0.075	
Average	9 to 5	-3.3†	30.09†		0.069	

† The first and last readings of the series were given half weight.

[To be continued.]

HARMONIC ANALYSIS OF THE DIURNAL BAROMETRIC CURVE AT WASHINGTON, D. C.

By W. J. BENNETT, B. S., Observer. Dated Charlotte, N. C., November 12, 1906.

Averages of hourly barometric readings at Washington, D. C., for fourteen years, 1891-1904, show a diurnal variation of .0637 inch, with a maximum occurring about 10 a. m., and a minimum about 4 p. m. There is another maximum occurring about 11 p. m., and another minimum at 3 a. m., tho the difference between these is only .0073 inch. Similar phenomena are found at all stations when hourly barometer observations are averaged, but at places having an oceanic climate the two maxima and the two minima are nearly equal. The day maximum and minimum might be accounted for by the diurnal change in temperature, the maximum barometer being connected with the low morning temperature, and the minimum barometer with the high afternoon temperature, but no such simple explanation will account for the night maximum and minimum. The method of harmonic analysis has been employed by Prof. F. N. Cole,¹ and by others to throw some light on the subject. When diurnal barometer curves from various stations are analyzed into their components it is found that the first, or diurnal component, varies greatly from place to place, its phases differing by several hours, and its amplitude, very large over continental interiors, becoming very small over the ocean. This component, then, appears to be due largely to local causes, especially to the diurnal range in temperature. The second component, with a semidiurnal period, is quite uniform over the world, and does not seem affected to any great degree by local causes. The third and fourth components have much smaller amplitudes than the first and second. They are more uniform in phase and amplitude than the first, but less uniform than the second.

¹ The Diurnal Variation of Barometric Pressure. By Frank N. Cole. Weather Bureau Bulletin No. 6. Washington, 1892.

The object of my study was to compare data obtained from the analyses of barometer curves for several different periods of years at the same place, and by such comparison to obtain some idea as to the reality, magnitude, and fluctuations of the first four components. Averages were taken of hourly barometer readings at Washington, D. C., (corrected for temperature and instrumental error only) for the periods 1891-1894, 1895-1899, and 1900-1904, and independent calculations were made for the whole 14-year period 1891-1904.

An outline of the mathematical development of the equations used may render clearer the results obtained. The ordinary cosine curve has the equation

$$y = P \cos x,$$

where P is the amplitude, or one-half the difference between the maximum and minimum ordinates. If the first maximum does not fall on the line $x=0$, the equation becomes

$$y = P \cos (x - M),$$

where M is the epoch or distance of the first maximum from the line $x=0$. For a curve of twice the frequency the equation becomes

$$y = P_2 \cos 2(x - M_2),$$

and for a curve of n times the frequency,

$$y = P_n \cos n(x - M_n).$$

For a curve made up of a number of superimposed cosine curves, as the diurnal barometer curve is supposed to be, we have

$$Y = y_1 + y_2 + y_3 + \dots + y_n,$$

and

$$Y = P_1 \cos (x - M_1) + P_2 \cos 2(x - M_2) + \dots + P_n \cos n(x - M_n).$$

Expanding:

$$Y = P_1 \cos x \cos M_1 + P_1 \sin x \sin M_1 + P_2 \cos 2x \cos 2M_2 + P_2 \sin 2x \sin 2M_2 + \dots + P_n \cos nx \cos nM_n + P_n \sin nx \sin nM_n.$$

Taking only four components, and letting

$$Q_1 = P_1 \cos M_1; Q_n = P_n \cos nM_n; \text{ and } R_1 = P_1 \sin M_1; R_n = P_n \sin nM_n, \text{ we have:}$$

$$Y = Q_1 \cos x + R_1 \sin x + Q_2 \cos 2x + R_2 \sin 2x + Q_3 \cos 3x + R_3 \sin 3x + Q_4 \cos 4x + R_4 \sin 4x.$$

There are eight unknown quantities, and if we have hourly means there will be twenty-four equations as x varies from 15° to 360°. The first and last of these will be:

$$Y_1 = Q_1 \cos 15^\circ + R_1 \sin 15^\circ + Q_2 \cos 30^\circ + R_2 \sin 30^\circ + Q_3 \cos 45^\circ + R_3 \sin 45^\circ + Q_4 \cos 60^\circ + R_4 \sin 60^\circ.$$

$$Y_{24} = Q_1 \cos 360^\circ + R_1 \sin 360^\circ + Q_2 \cos 720^\circ + R_2 \sin 720^\circ + Q_3 \cos 1080^\circ + R_3 \sin 1080^\circ + Q_4 \cos 1440^\circ + R_4 \sin 1440^\circ.$$

By the principle of least squares, these equations may be reduced to eight, of which the first will be

$$12 Q_1 = Y_{24} - Y_{12} + (Y_1 - Y_{13} + Y_{23} - Y_{11}) \cos 15^\circ + (Y_2 - Y_{14} + Y_{22} - Y_{10}) \cos 30^\circ + (Y_3 - Y_{15} + Y_{21} - Y_9) \cos 45^\circ + (Y_4 - Y_{16} + Y_{20} - Y_8) \cos 60^\circ + (Y_5 - Y_{17} + Y_{19} - Y_7) \cos 75^\circ.$$

The equations are given in full by Professor Ferrel (Report of the Chief Signal Officer, 1885, Part 2, page 342).

From the values of Q 's and R 's so obtained the values of P 's and M 's are calculated by the relations

$$\frac{R_n}{Q_n} = \frac{P_n \sin nM_n}{P_n \cos nM_n} = \tan nM_n$$

$$\log \tan nM_n = \log R_n - \log Q_n.$$

$$P_n = \frac{Q_n}{\cos nM_n}; \log P_n = \log Q_n - \log \cos nM_n.$$

In these calculations careful attention must be paid to plus and minus signs, since $+Q_n$ and $+R_n$ put the angle nM_n in the first quadrant, $-Q_n$ and $+R_n$ in the second, $-Q_n$ and $-R_n$ in the third, and $+Q_n$ and $-R_n$ in the fourth. The factors P